Introduction

In an attempt to mitigate the damaging effects of greenhouse gas emissions, international governance has legislated for the reduction of energy use and CO_2 emissions. In Scotland (the setting for this research) the Climate Change (Scotland) Act 2009 requires the Scottish Government to reduce carbon emissions from 1990 levels across all sectors by 42 per cent by 2020 and 80 per cent by 2050, as set out in the Energy Efficiency Action Plan. As domestic energy use represents 30% of total national energy use [1] there can be little doubt over the role this sector has to play in helping to achieve the targeted reductions.

Whilst for new buildings this is being addressed through building standards, with the ambition of whole life zero carbon by 2030 [2], a more pressing problem is that an estimated 75% of the stock currently in existence will still be in use by 2050 [3] and much of this stock has a very poor performance. Local authorities and housing associations have undertaken a number of measures to improve the thermal performance of their existing stock but more recently this is being driven the need to comply with the Energy Efficiency Standard for Social Housing (EESSH). This standard is based on minimum Energy Performance Certificate (EPC) energy efficiency ratings. The requirements vary depending on the type of property and the existing heating system.

Two problems arise with the implementation of this. Firstly, EESSH is based primarily on thermal measures, such as wall and loft insulation, double glazing and improved heating system. The standard makes no mention of requirements or consequences in terms of other environmental impacts such as ventilation or Indoor Air Quality (IAQ). Secondly, compliance is based on EPCs which are achieved at design stages with theoretical assumptions and - as is usual in the construction industry - there is virtually no measurement of actual performance of these measures. This raises the question of whether the standards are being met in practice, and what the unintended consequences might be on IAQ. This paper describes a research project which is investigating the as-built performance of energy efficiency retrofit measures.

Methodologies

The project is a collaboration between the Mackintosh Environmental Architecture Research Unit (MEARU) and John Gilbert Architects (JGA), supported by Innovate UK through Knowledge Transfer Partnership (KTP) funding. The aim is to develop a service – Hab-Lab – that uses Building Performance Evaluation (BPE) expertise within MEARU to undertake evaluations of social housing in the west of Scotland that have either undergone refurbishment, or that are due to refurbishment. Social landlords are becoming increasingly aware that there are potential unintended consequences of retrofit measures and the project has formed a partnership with five council and housing association landlords to evaluate the actual thermal and environmental performance of a range of house and construction types. The Hab-Lab approach offers a range of possible processes dependant on the nature of the investigation ranging from assessment of compliance, testing of specific components (e.g insulation systems), testing and monitoring of energy and environmental conditions in buildings, to handover and POE processes.

The project has undertaken studies in post-war housing in Scotland that have been subject to retrofit measures intended to meet EESSH requirements. Field investigations include airtightness testing, thermography, testing of equipment and services (e.g. ventilation and heating systems); monitoring of environmental conditions (temperature, relative humidity, and CO_2 levels); and energy consumption under varying seasonal conditions. The case study examples include 5 No. pre 1945 solid brick wall flats, 2 No. post 1945 no-fines concrete flats, 2 No. Pre 1914 traditional sandstone flats, 2 No. interwar brick cavity flats and 2. No post war Atholl steel flats. These are directly representative of over 3000 houses of the same construction.

Results and discussion

The results show that there are discrepancies between predicted (or expected) performance. These include performance gaps in energy performance such as insulation values some 2.3 times higher than predicted; significant thermal bridging at wall floor junctions and around services, or missing insulation in key areas. In the case study buildings 37% did not meet the EESSH standards in practice. Particular issues were noted with external wall insulation (EWI) systems. These are becoming widespread as economies of scale have made it more cost effective, and it does address problems of thermal bridging and water penetration that may occur with cavity fill, and internal disruption that accompany internal insulation. However, the current funding for EWI systems only allows the system to go down to the floor level. This results in the original brick wall, particularly the inner leaf, acting as a cold bridge at the floor level. This is exacerbated by the tendency not to include insulation in the floors. It was also common to find that insulation was not returned at window reveals, and that it was frequently omitted around external services. As a consequence, thermal bridging of construction was commonplace.

Poorer than expected thermal performance is leading to a number of environmental consequences. In several of the case studies fuel costs and poor control were leading to intermittent or partial heating regimes, during which parts of the dwellings were cold. Overall 44% of the homes did not meet recommended values for comfort. As temperatures reduced, high levels of relative humidity were observed. High sustained period of RH were seen, with three flats having RH between 55-70% for 80% of the time and bedrooms having RH over 70% for 20% of the time.

A further cause is deficiencies in the ventilation provision. In the majority of cases, thermal improvements (which had also affected air permeability of the dwellings with 88% of the dwellings having either poor or excessive air permeability) had not been followed up by improved ventilation. Problems included lack of ventilation systems, underperformance of installed systems, and lack of occupant awareness of the use of systems. Monitoring of CO_2 levels in the home indicated that 89% of the homes had CO_2 levels over 1000ppm for sustained periods of time. The combination of high relative humidity, poor ventilation and thermal bridging has resulted in 55% of dwellings showing signs of condensation or mould growth, the health effects of which are well established

Conclusion

It is clear that we need to improve the thermal performance of existing buildings, but it is also important ensure this is not at the expense of IAQ. The key findings from the case studies are that improvement measures need to be considered in a holistic manner to account for unintended consequences. Whilst improvements in insulation and double glazing are important components in reducing heat loss and fuel poverty, they need to be considered in the context of the whole house performance. The efficacy of improvements to existing buildings will always be compromised by the existing construction and form – therefore additional care and attention is needed to ensure that environmental performance is not compromised by well-intended, but ultimately incomplete solutions. Further work is on-going to undertake measurements of indoor pollutants that may be exacerbating IAQ problem – an observed example is that in houses with mould, attempts are often made to mask the unpleasant smell with the use of chemical based air fresheners, themselves a source of volatile organic compounds (VOCs).

The Hab-Lab approach is able to undertake pre-retrofit monitoring to determine the existing energy and environmental performance and propose a suite of measures that may achieve a more holistic solution. For example, this includes measurement of u-values, thermography and air permeability testing which can be used to determine the exact provision required, and improvements to heating and ventilation system, both in terms of technical provision, but also occupant guides and information.

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References

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